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Preliminary Report of the Expedition to Aswan to Observe the Total Solar Eclipse of August 30, 1905.

By H. H. Turner, D.Sc., F.R.S., Savilian Professor of Astronomy in the University of Oxford.

(Received October 19, 1905.)

1. *General Objects.*—The particular pieces of eclipse work kept steadily in view by the writer during recent years are—

(*a*) The determination of the brightness of the corona by photographic methods at different distances from the sun's limb.

(*b*) The determination of the fraction of this light radially polarised.

Attention was directed to both these objects on the present occasion and in addition an opportunity presented itself of making a trial of—

(*c*) The use of long focus mirrors in eclipse work.

This question of long focus mirrors was brought before the Joint Permanent Eclipse Committee three years ago, and a Sub-committee of three (Dr. A. A. Common, Sir J. N. Lockyer, and Professor H. H. Turner) was appointed to deal with the matter. Dr. Common was making two or three mirrors for trial when his lamented death put an end to the experiments. While the remaining members of the Committee were considering how to proceed, I learnt of the existence of a 2-foot mirror of 120 feet focus, with cœlostat of 28 inches diameter, constructed by Mr. J. H. Reynolds, F.R.A.S., of Birmingham, and mounted in his garden; and I further gathered that he would like to try the instrument in Egypt at the Eclipse of 1905, as he had already another reason for visiting the country about that time. He had, in fact, been so much impressed, on the occasion of two previous visits to Egypt, by the suitability of the climate for astronomical work, and the desirability of having a large telescope there, that he had offered to present to the Helwan Observatory a reflecting telescope of 30 inches aperture and 11 feet 6 inches focal length, the mirror of which was made by the late Dr. Common, F.R.S., and the mounting of which was to be designed and constructed by Mr. Reynolds himself. Before accepting this offer, Captain H. G. Lyons, Director-General of the Egyptian Survey, under which department the Helwan Observatory is placed, did me the honour to ask for my opinion whether such a telescope could be profitably employed in Egypt and what work it could most suitably do. There could be no hesitation in replying to the former question in the affirmative, and as regards the latter, since the low latitude of Egypt brought within reach many new nebulæ not obtainable from observatories already equipped with large instruments, it was obvious that, for some years at any

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rate, the particular work of the reflector which the maker of the mirror had himself initiated, could be pursued to the utmost advantage. Captain Lyons accordingly accepted Mr. Reynolds' offer, and at the meeting arranged for the discussion of it, he also gave Mr. Reynolds and myself a most cordial invitation to Egypt for the eclipse, promising that he and the Survey Department would do all in their power to assist us; a promise which he literally fulfilled. Under these circumstances I felt justified in asking the Joint Permanent Committee to sanction the addition to our programme of the trial of this large telescope, which Mr. Reynolds freely put at our disposal; and further to allow Mr. Bellamy to accompany me, since Mr. Reynolds himself could not arrive in Egypt till a few days before the eclipse.

(*d*) Finally I was asked by Mr. E. W. Maunder to take charge of one of a pair of Goerz lenses, which I understand were lent for the expedition by the firm on the suggestion of Mr. A. Reichwein. Mr. Maunder took the other with him to Labrador, and arranged a definite programme for use with both instruments, with a view to stereoscopic combination of the pairs of photographs thus obtained at the ends of the line.

We were fortunate in being able to hand over this instrument, after carefully focussing it in Aswan during the week preceding the eclipse, to the care of Mr. R. T. Günther, of Magdalen College, Oxford, who came to Egypt at his own expense and volunteered to assist the expedition.

(*e*) One or two possible additions to the programme had to be reluctantly abandoned. Especially do I regret that it was not possible to do anything in the direction suggested by Mr. C. E. Stromeyer for accurately observing the positions of the limits of totality on the earth's surface. We found on actually arriving in Egypt that all available energy was used up on the existing programme, and to add anything would seriously endanger the whole.

2. *Personnel.*—The expedition from England thus consisted of the following persons:—

Prof. H. H. Turner.
Mr. F. A. Bellamy. } From the Oxford University Observatory.
Mr. J. H. Reynolds, of Birmingham.
Mr. R. T. Günther, of Magdalen College, Oxford.

But these would have accomplished little without the aid of the following officers of the Survey:—

Captain H. G. Lyons, Director-General.
Mr. J. I. Craig.
Mr. H. E. Dickinson.
Mr. E. M. Dowson.
Mr. J. R. Herbert.
Mr. J. Kearney.
Mr. B. F. E. Keeling.

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Mr. Keeling took charge of all the operations of erecting piers and shelters and similar work which would have been extremely difficult to strangers unacquainted with Arabic. He worked untiringly throughout, and we owe him a great deal, especially for his exertions during the last few days in getting the large telescope mounted at very short notice. Mr. Kearney developed the plates in Cairo, under the admirable conditions available at the Survey Department. All the gentlemen named took an important share in the operations during totality, while Mr. W. M. Aders, who was acting as correspondent for the 'Egyptian Gazette,' also kindly took charge of an exposure, and Mr. Ball helped Mr. Bellamy with his plate-holders.

Of Captain Lyons himself, and what he did, not only for the British Expedition, but for the American and Russian Expeditions, it would be difficult to write adequately. In preliminary suggestions, in arrangements for meeting us on arrival and seeing us comfortably established, in placing the resources of the Survey Department at our disposal, and in actual personal assistance in the work, he was equally generous.

3. *Dates and Itinerary.*—The bulk of the Oxford instruments were placed on the Prince Line Ss. "Trojan Prince" in London, on which Mr. Bellamy took his passage on Monday, July 17. The 13-inch objective of the astrographic telescope was placed in his cabin; and the box containing it was handled throughout the expedition either by him or by Professor Turner. The "Trojan Prince" took longer than usual over the voyage, not arriving at Alexandria till Saturday, August 5.

Mr. Keeling went to Alexandria to meet the boat, and saw the instruments put on the train for Aswan, where we found them on our arrival on Tuesday, August 8.

Professor Turner left Oxford for Marseilles on Thursday, July 27, and there joined the P. & O. steamer "Himalaya," on which had been placed in London two cases of instruments and plates which could not be got ready for the "Trojan Prince." The P. & O. Company not only allowed these to go as passengers' baggage, but courteously carried them free of charge.

Mr. Reynolds was not able to leave England until August, and joined the Orient steamer "Oroya" at Marseilles. This boat Mr. Günther also joined at Naples on August 20, and it arrived at Port Said on Friday, August 25. Mr. Reynolds' large telescope was also on this boat, it having been found impossible to send it earlier owing to circumstances which will be mentioned in §§ 26, etc. Mr. Reynolds arrived at Aswan with his instruments on Saturday afternoon, August 26, just four clear days before totality.

We have to cordially thank the Egyptian railways for transporting us and our instruments from the ports of arrival in Egypt to Aswan, and back again, free of charge.

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4. *Station.*—The central line cuts the Egyptian railway close to Khattara in latitude 24° 12′. Captain Lyons was prepared to make arrangements for establishing the expeditions there, either by encampment or by providing dahabeahs; but, on learning that it was not of vital importance to be actually on the central line, he unhesitatingly recommended our taking up a position at Aswan in latitude 24° 6′, where only 3 seconds of totality was lost, and where there were all the resources of civilisation to be had. The large Savoy Hotel was open all the summer, and we were very comfortably quartered indeed.

It was, however, practically impossible to select a site before our arrival. To have done so would undoubtedly have been advantageous in allowing of the erection of piers in time for them to settle firmly; but the available and suitable sites were neither numerous nor large, and the choice was a matter of some difficulty. The managers of the hotel very kindly put their grounds at our disposal, and ultimately sites were chosen in the grounds for all three expeditions. But the hotel is on an island, reached from the railway by boats; and, after some experience of the conveyance of instruments across, and their handling on the island, it was felt that there would be difficulties and delays attending the transport of Mr. Reynolds' telescope thither; and when it became known how short the time available for its erection would be (four days only) it was decided to abandon the site chosen for it in the hotel grounds, and to substitute one at the railway station, where it could be mounted immediately on arrival. On visiting the railway station it was seen that if the cœlostat pier could be erected on the station platform, and that for the concave mirror almost on the public road, the rays between the two mirrors would pass over the intermediate area, which was a sunken garden, at a height of several feet, obtaining the effect of raising the piers to a considerable height. On making inquiry whether permission could be obtained, it was at once given; and thus, by the kindness of the railway authorities, a site having conspicuous advantages was obtained. It was further felt that if the ground could be well soaked the disturbance from radiation would probably be sensibly diminished. While we were debating the best method of doing this, the local fire-brigade happened to be drilling, and Mr. Keeling promptly asked whether they could help us. The affirmative reply was equally prompt, and on the day of the eclipse the ground was flooded three times, at intervals of some hours.

The position of the stations may be taken approximately as—

Latitude ..... 24° 5′·5 N.
Longitude ..... 32° 52′·5 E.

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An American expedition under Professor Hussey, and a Russian expedition from Pulkowa and Pawlowsk, were established in the same hotel, and erected their instruments also in the grounds; except that Dr. Doubinsky, of Pawlowsk, set up his magnetic self-recording apparatus in a tomb (No. 32 of 'Grenfell's Tombs') on the west bank of the Nile.

5. *Meteorological Conditions, etc.*—The chief characteristic of the weather was, of course, its steadiness. The following figures from the Daily Weather Report, issued by the Survey Department, will sufficiently illustrate this. The observations are made at 8 A.M.:—

Date.	Barometer corrected.	Wind.		Cloud.	Temperature, Centigrade.			Humidity.
		Dir.	Force.		Max.	8 A.M.	Min.	
					°	°	°	
Aug. 5	756·1	N.	Very light	Clear	42	31·6	25	29
6	756·1	N.	Very light	Clear	42	32·4	24	28
7	755·7	N.	Very light	Clear	43	32·2	26	19
8	756·7	N.	Very light	Clear	43	30·4	25	23
9	757·2	N.	Very light	Clear	41	31·2	24	35
10	756·4	N.W.	Very light	Clear	42	32·6	25	26
11								
12	756·3	N.	Very light	Clear	42	32·6	25	27
13	757·2	N.	Light	Clear	41	30·2	26	29
14	756·2	N.	Light	Clear	39	29·8	24	22
15	756·4	N.	Very light	Clear	41	30·6	24	23
16	755·9	N.	Light	Clear	42	32·8	26	21
17	757·1	N.	Light	Clear	42	31·6	26	25
18								
19	755·0	N.E.	Moderate	Clear	42	29·8	26	27
20	755·0	N.	Light	Clear	42	30·4	24	30
21	755·8	N.	Very light	Clear	42	30·4	25	33
22	755·2	N.E.	Very light	Clear	42	30·6	24	29
23	755·7	N.	Fresh	Clear	42	33·6	29	33
24	755·8	N.	Fresh	Clear	42	30·2	27	31
25	756·4	N.E.	Fresh	Clear	40	29·6	26	42
26	756·1	N.	Very light	Clear	40	29·2	24	46
27	756·2	N.	Very light	Clear	40	29·6	23	53
28	756·3	N.	Very light	Clear	40	29·2	25	44
29	756·5	N.	Almost calm	Clear	41	30·2	24	50
30	757·8	N.	Very light	Clear	40	29·2	22	49
31	757·4	N.	Almost calm	Clear	40	29·6	22	51

There was thus a steady north wind, light in the daytime, but often strong at night, and as sand came with it, it was advisable to have screens to the north of the instruments, though nothing really kept the sand out. Fortunately everything was so dry that the sand was soon blown away again, and our clocks suffered far less than might have been expected.

The sky was almost permanently clear, with one notable exception. On the afternoon of August 21 the sky clouded over completely and quite

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thickly. The sun was quite invisible from before the time corresponding to first contact until sunset. Had August 21 been the day of the eclipse we should have seen nothing at all. Such facts are worth remembering in connection with eclipses. In 1889 (December) there was considered to be a practical certainty of fine weather in West Africa, and yet it was cloudy for four days at the time of eclipse. It seems doubtful whether anything approaching real certainty of a clear sky can be attained.

We had no rain, and the air was very dry, though the humidity rose sensibly about August 25 to 31. The high temperature was, therefore, not so trying as might be expected. But in many ways we were constantly reminded of it. On dressing we found our clothes hot and dry; metal work was often scorchingly hot, especially if left exposed to the sun for a few minutes: indeed, almost anything might happen in the sun: for instance, a stick of ebonite, which Professor Doubinsky, of the Russian Expedition, stuck in the sand to make an experiment on atmospheric electricity, was soon seen to be bending over, partially melted.

The Nile was steadily rising during our stay at Aswan, though the flood was much below the average.

Insects and small reptiles were very numerous. There were very few mosquitoes or sand flies, and not very many flies, though the few were very persistent. But spiders, lizards, scarabs, scorpions, and other animals swarmed among our instruments, fortunately without doing any particular harm. When the tube of the 13-inch was covered with cloth a scorpion of some size took up his abode therein, and though we often saw him we failed to either catch or dislodge him until the whole was dismounted after the eclipse. Any alterations in the instrument were thus made with some wariness.

There were often clouds on the horizon, but sometimes it was wonderfully clear. We saw a bright star set behind a low hill with all the suddenness of an occultation. On the day following the eclipse (August 31) the horizon was distinctly hazy, but we caught sight of the 26-hour-old moon at 6.45 local time, and photographed it in 3 seconds with the fixed Goerz lens—it being quite out of the reach of our cœlostat and 13-inch. The next night it was easily photographed with both instruments, the earth-shine plainly showing on the pictures. [To give an exposure of 10 seconds the cœlostat was slightly altered for the moon's motion. The altitude of the axis was dropped 47′, and the clock was made to go 2·3 seconds slow in the minute.]

The dry climate was very hard on wood of all kinds. We were warned of this, and in arranging plate-holders I consulted Messrs. Watson and Sons

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whether they had not better be in metal; but they expressed confidence that they could make them in wood to stand the climate. The confidence was only partially justified, several of the plate-holders warping considerably; and if this was so in cases where special care was taken it was only natural that worse should happen in other cases. A large amount of time, during the expedition, was consumed in refitting things that no longer fitted at all. Fortunately most of the changes seemed to take place at once and then to be arrested, so that it was possible to make alterations permanent.

The exceptional dryness of the climate and the high temperature naturally brought troubles in developing plates. Solutions evaporated so rapidly that it was difficult to judge of their strength at a given moment. Of course, ice was used plentifully, otherwise development was impossible; but even then it was not easy to work. Sodium sulphite melted, and this did no harm so long as the bottles were well sealed; but when they were merely corked the salt appeared to decompose and gave trouble. All these troubles, however, fell lightly on us who had merely preliminary plates to deal with, and could hand the eclipse plates over to Mr. Kearney's experienced hands. Professor Hussey bore the brunt of them in Aswan.

This last fact had one unfortunate consequence. It was hoped that Professor Hussey might have been able to make a critical examination of the "seeing" at Aswan, which would have been particularly valuable owing to his exceptional knowledge of climates, for it will be remembered that on behalf of the Carnegie Institution, who were contemplating the erection of new observatories, he visited not only Mount Wilson, in California, where the new solar observatory has since been established, but Australia and Tasmania, in search of a site for an observatory in the southern hemisphere, and has thus added largely to his already wide experience at Mount Hamilton. He had not a leisure moment before the eclipse, but afterwards he hoped to make use of the 8-inch objective which Captain Lyons kindly had sent down from Helwan, and we all looked forward to the result of his observations with great interest, as he did himself. But the development of the plates was so anxious and slow a process as to occupy every night available after the eclipse, and he was compelled, with the greatest reluctance, to give up the idea of finding sufficient time to make the tests which he considered necessary to give any information of value.

6. *Piers, Huts, etc.*—Brick piers with a concrete foundation were built under Mr. Keeling's direction. It was impossible to get a rock foundation, and we did the best we could in the sandy soil. In the exceptionally dry climate of Aswan, the difficulty was to keep the mortar and cement wet long enough to give a solid setting, but sufficiently steady results were

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obtained. According to a practice found useful in previous eclipses, blocks of wood were introduced into the piers for the attachment of apparatus by screwing down, or for binding with cords round projecting ends. In this case the method was not successful. The wood absorbed any moisture used for the cement and bricks and swelled, cracking several of the piers, but fortunately no serious damage to the observations resulted.

Shelters were necessary because of sun and wind, though not for rain. They were made by covering a skeleton wooden framework with matting arranged in panels. The straw mats were a well-known local commodity, and we found many of the windows of the Savoy Hotel closed up with them during the summer as a protection against the fierce sun. They measured 10 feet × 6 feet. With a simple wooden framework they were rigid enough to be easily placed in position by a single person if necessary, and were heavy enough to remain in place when merely laid on the roof, though the wind was often strong. In the rainless climate they gave all the advantages of a sliding roof at a trifling cost.

The mounting of the large telescope is separately referred to under § 31.

7. *Instruments Mounted in Savoy Hotel Grounds.*—At previous eclipses (1896, 1898, 1900) I had used one of the "double tubes" constructed for the eclipse of 1893, pointed to a 16-inch cœlostat, the polariscopic apparatus being attached to this tube. In 1900, when photographs with the separate components of the "Abney" lenses were discontinued, one half of the tube was set free, and in the other half polariscopic apparatus was arranged by Mr. Newall and myself conjointly. In 1901 Mr. Newall kindly took charge of the same instrument in Sumatra, but finding difficulties with my Iceland spar prism apparatus (as explained in §17), he omitted it and substituted another arrangement. It was an obvious convenience for him to have the same double tube arranged in the same way for the present eclipse, and quite as easy for me to take out another instrument, especially as Mr. Newall kindly handed over to me the 16-inch cœlostat and purchased another for himself. It became, therefore, necessary to decide on (*a*) a telescope for simple photographs of the corona which might also afford material for determining its general brightness in continuation of previous work; and (*b*) apparatus for taking the photographs in polarised light.

The Astrographic Telescope.

8. For the former purpose we decided to bring out the astrographic telescope, or rather the object-glass of it. Our plates for the catalogue being completed, there was no risk of a breach of continuity in the series, and I

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was glad to learn that the Astronomer Royal had also decided to take out the Greenwich corresponding telescope.

9. It was decided not to dismount the tube, partly because the dismounting would have been a serious operation and partly because the plate end is arranged for plates 16 cm. square, and it was hoped to use a larger plate for the corona. A new tube was constructed from eight pieces of gas-pipe, each 6 feet in length, with joints so that they could be readily screwed together into four 12-foot rods. These were passed through three rectangular blocks of sequoia wood 2 inches thick, one block at each end and one in the middle. Circular apertures were cut in the middle block and in the end block to which the object-glass was bolted, and a rectangular aperture in the other end block, to admit a box-like structure for the plate-holders. The whole was ultimately wrapped, first with blackened wire at wide intervals, next with black cloth, and finally with canvas. The arrangement worked very satisfactorily, being light and easily transported, and affording means of making the necessary adjustments.

10. *Focussing, etc.*—Each block of wood was held in place by eight nuts screwed on to the gas piping, two nuts on each pipe against opposite faces of the block. For focussing it was only necessary to turn (say) the four inner nuts through a whole turn, or half a turn, and screw the outer ones up so that the wood was again held tight. Screwing the nuts by different amounts on the different rods gave corrections for tilt of plate or objective. Observations for detection of this tilt were made in the case of the plate by putting a silvered mirror in its position, and from the O.G. end measuring the position of an object and its image with a foot-rule in daylight until they were symmetrically placed. In the case of the objective, star images were examined at equal distances on opposite sides of the plate, and the objective tilted until symmetry was obtained. The focussing of the instrument was first adjusted indoors with artificial light by using the cœlostat mirror to reflect the beam back through the objective, and completed by photographs of stars with the tube in position.

11. The box-structure for receiving the plate-holders for 10-inch × 8-inch plates was made of papier mâché, from some spare pieces left from our new dome: and it stood very well, far better than the wooden blocks, which, indeed, did not stand well at all. Sequoia wood was selected as we heard that it made excellent plane-tables for surveying; and it certainly remained flat, but it contracted across the fibre, so that the circular aperture cut for the objective became an ellipse, with minor axis too small to admit the cell. A good deal of scraping away was necessary on more than one occasion to get a satisfactory fit again, and the bolt holes were of course all out of place.

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This is one instance of many troubles with woodwork encountered not only by us but by the other expeditions. Small wonder if more than one vow was made never to trust to wood again in future expeditions. And yet I do not feel sure that this is the right inference from our experience. It must be remembered that it was altogether exceptional, and yet that the troubles, though numerous and often apparently serious, were all got over satisfactorily, so far as we know at present. If this can be achieved in an extreme case, it would seem to show that wood can generally be used, and there is no doubt that this means a great saving in weight and expense as compared with metal. But two precautions should certainly be taken in using wood: firstly, to get it as good and well-seasoned as possible, and secondly, to be at the eclipse station as early as possible, so as to give time for correcting unforeseen deviations. As regards the second, we have here only an additional reason for spending more time at the eclipse station, for which course experience has already suggested so many others.

12. The plate-holders themselves were specially made by Messrs. Watson and Sons, of Holborn, with the form of flap-exposing shutter adopted for the "double-tube" holders. Indeed the pattern of these holders, which were made by Messrs. Watson and Sons for the 1893 eclipse, and which have worked admirably at all eclipses since then, was closely followed in the present instance. As already mentioned the woodwork did not offer a perfect resistance to the climate, but it behaved very well on the whole.

The Cœlostats and Guiding Telescope.

13. The telescope tube was laid approximately horizontal, in the azimuth 10° south of west, and pointed to the 16-inch cœlostat used in the 1896, 1898, 1900, and 1901 expeditions (in the last case by Mr. Newall). The 13-inch objective practically used up the whole mirror and it was thus not possible to point any other telescopes to the same mirror. But we had in our possession at Oxford a 12-inch mirror mounted in horizontal Y's, so that it could reflect any object on the meridian into a fixed direction, according to the scheme for a photographic transit-circle,* which other work has hitherto prevented our carrying out.

It was found that by tilting the base plate to the latitude of Aswan, bringing the axis into the same line as that of the 16-inch cœlostat, and joining up the two instruments, the clock could be made to drive them both, especially when a string was wrapped round a wheel on the axis of the 12-inch, and led over a pulley to a weight which thus constantly urged the

* 'Monthly Notices R. A. S.,' vol. 57, p. 349.

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mirrors round and took up a great part of the work that would otherwise have fallen on the clock.

14. *Guiding.*—But we were naturally anxious as to the performance of the clock, which was thus given a double responsibility, and it was determined to watch its performance during totality, just as a guiding telescope is used in taking a star photograph. Even without the additional reason of the present instance, experience has suggested such a course. There may be a sudden fall of temperature at an eclipse which may disturb the rate of a clock, however carefully adjusted previously, or accidents of other kinds might happen. The first-rate importance of good clock driving was clearly pointed out by Professor Schuster in his report on the 1886 eclipse,* and has several times been brought before the Joint Permanent Committee. It was decided at one time to have electrical control for the eclipse clocks, but there are obvious difficulties in such a course and they have hitherto prevented its being adopted. It was determined therefore to make an experiment on guiding by hand.

15. If a refracting telescope is pointed to the cœlostat, the observer at the eye end is at a distance from it. He can use the slow motion, which is worked by a cord, to correct any defect in driving; but this method is unsatisfactory in many ways, the pull of the cord being liable to set up tremors in the instrument. It was preferred to use a reflecting telescope, which brings the observer back near the clock, and to adjust the clock rate if necessary. It was found that in the 10 minutes before totality the driving sensibly altered, but the rate was readily adjusted. During totality the alteration of rate continued, but there was no difficulty in continuing the adjustment also. The result of the experiment suggests that this operation of watching the clock throughout totality should be an essential part of an eclipse programme. Even if the clock goes well, it is a satisfaction to know it; and, so far as we know, clocks often do not go well. The change in rate at Aswan can scarcely be ascribed to the fall of temperature, which was slight, unless we include the effects of radiation, which were, of course, enormously reduced. To the body it became distinctly cooler, as when one walks from the sun into the shade; and, though the carefully-shaded thermometer showed little or no trace, it is conceivable that the clock, which was only roughly protected, may have been affected like the body rather than like the thermometer. At any rate, one other clock, at least, also felt the change, that used by Dr. Okoulitsch, of Pulkowa. The possibility of change had been mentioned to him, and he looked for it carefully, with the result that he found that the rate, which had been sensibly constant before, began

* See 'Phil. Trans.,' 1889.

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to change during the partial phase, and was still changing a few minutes before totality, when he had to leave it.

16. As regards the actual arrangement adopted: a small plane mirror, kindly lent by Mrs. McClean, was attached to the axis of the 16-inch cœlostat at the north end, making in all three mirrors on the same axis. The rays were thrown on to a 10-inch concave mirror of 78 inches focus, mounted on a heavy wooden stand which could readily be adjusted on the sandy ground. They were focussed on the film of a 10-inch × 8-inch photographic plate (a trial star plate—no longer wanted), mounted in a strong wooden support. A large field was thus visible, of which any point could be selected for examination with an eye-piece held on a long rod by hand. Lines were scored with a knife freely on the film for reference marks, as it was not known where a prominence would come on the plate. Before totality, the limb of the crescent was watched. During totality, no difficulty was found in picking up a prominence to watch for the first minute, and, before it had disappeared, the amount of slight acceleration to give to the clock had practically been settled. The rate was verified by means of the reappearing prominences towards the end of totality. There was some interruption midway, owing to the accidental obstruction of the reflected beam by the operator who was exposing at the 13-inch objective. Better arrangements to avoid this risk, could doubtless be made on another occasion.

The Polariscopic Cameras.

17. *Attempts with Iceland Spar Prism.*—For the 1896 eclipse a method was devised of obtaining two images of the corona in lights polarised in directions at right angles, with a prism of Iceland spar.* The 1896 eclipse was cloudy; but the same apparatus was taken to India in 1898 and successfully used, though the pictures were on a very small scale. To obtain a larger scale, new lenses were used in Algiers in 1900, and there was revealed some defect in the prism, of the nature of an internal reflection. Before the 1901 eclipse it was sent to the makers (Messrs. Ph. Pellin, of Paris) for examination, and returned by them as satisfactory; but Mr. Newall, who had kindly offered to take out the apparatus to Sumatra, found preliminary trials so unsatisfactory that he did not use it. On preparing for the present eclipse, attempts were first made to get a larger and better prism, but failed, owing to some not altogether intelligible difficulties in the supply of Iceland spar. It was then determined to do the best possible with the existing prism, which was thoroughly tried at Oxford and then again sent to the makers with an explanation of the defect. It was not received back from them in time to

* 'Roy. Soc. Proc.,' vol. 67, p. 95.

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make further trials at Oxford, but was taken out to Aswan and examined there, when it was seen at once that the defect was not cured, there being a faint spurious third image in addition to the two which should appear. Hence this method was abandoned, owing to the practical difficulty of getting a satisfactory prism.

18. *Horizontal Reflection Apparatus.*—Meanwhile it had been determined to try in addition the method suggested by Professor Schuster, of photographing the corona after reflection from a plane glass surface at the polarising angle. Some fine glass prisms* were kindly lent by Mrs. McClean from the apparatus belonging to her late husband. One of these, $9\frac{1}{2}$ inches $\times$ 7 inches and of angle 13°, was placed in front of a photographic doublet of $5\frac{1}{2}$ inches aperture and 30 inches focus; stopped down for three plates to $3\frac{3}{4}$ inches ($f/8$) and for three other plates to $1\frac{7}{8}$ inches ($f/16$). The stopping-down was done to make quite sure that the aperture was filled with light from the prism, which at an oblique incidence of 60° had only an effective width of $4\frac{3}{4}$ inches. The prism was set by means of the Iceland spar prism, the defect in which did not matter for this purpose. A small hole in the centre of the telescope field was illuminated by a candle, and the emergent beam, after reflection from the glass prism, was examined with the Iceland spar, to see if one of the images could be made to disappear by rotation. It was found that the prism could be set very exactly to the right position in this way. The angle was measured and recorded after the eclipse by an Abney level, turning the prism slope into a vertical plane and measuring the relative slope of prism and telescope tube, and found to be $57°{\cdot}0 \pm 0°{\cdot}2$. The above apparatus was used in a horizontal plane, and flexure may have slightly altered the angle on turning it round, though the mounting was firm, but the accuracy obtained is probably sufficient. In suggesting the method Professor Schuster pointed out that for a range of several degrees near the polarising angle the polarisation is very nearly complete, indeed, but for this, the method would scarcely be applicable to an object like the corona, which extends for more than a degree.

19. *Vertical Plane Apparatus.*—The apparatus mentioned in the last paragraph, used up a considerable part of the 12-inch mirror, but there was plenty of room for the Iceland spar apparatus which was prepared for use if the prism could be got right. On finding the Iceland spar prism still defective it was decided to use another reflecting prism in a vertical plane. But no telescope of the size of that already mentioned was available. After some troublesome experiments in fitting in apparatus, which comes in awkward

* Prisms were used in preference to plates to avoid the reflection from the other surface, which, in the case of a prism, is thrown in a totally different direction.

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places with these oblique angles and is apt to cut off the incident beam from the cœlostat mirrors, especially with a low sun such as we had for the eclipse, an arrangement was arrived at by which a small camera of 2 inches aperture and $9\frac{1}{2}$ inches focus, for which, however, only two plate-holders were available, was pointed to a prism face of 10 inches × 4 inches also kindly lent by Mrs. McClean, the plane of reflection being vertical and the angle (set as before by means of the Iceland spar prism) being found to be 61°·4. The measurements could in this case be made with the apparatus *in situ*. The exact angles for complete polarisation will be determined in the laboratory when the instruments are delivered again at Oxford, for comparison with these measurements. Attention may be drawn to the great convenience of the Abney level for measures of this kind. An accuracy of 10′ is readily attainable with this handy instrument.

Operations with the Instruments described in §§ 7 to 19.

20. The programme prepared for totality, and substantially carried out, was as follows:—

13-inch Astrographic Objective for Photographs of the Corona on 10-inch × 8-inch Plates.

Slide.	Exposure.	Plate.	Remarks.
	sec.		
1	1	Rocket	
2	10	Double-coated Rocket	
3	20	Green sensitive.....	With green colour screen.
4	5	Rocket	
5	11	Photo mechanical	
6	2	Rocket	Not exposed.

Mr. Bellamy put in the slides and Mr. Dickinson exposed at the objective. Mr. Ball received and wrapped up the plates as they were exposed.

21. Between Nos. 3 and 4 an enlargement was attempted by Mr. Kearney, with an ordinary enlarging lens of 13-inch focus placed behind the primary focus so as to give an enlargement of five diameters. But it was not sufficiently realised until too late how large the camera lens should be in order to take in the cones of rays from the 13-inch objective properly, and it was seen at the last moment that the result would be a failure. That it was not realised earlier was, of course, regrettable; but it is some excuse for the error that the trial of the camera was necessarily delayed by the difficulties of dealing with woodwork.

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All the plates were developed by Mr. Kearney in the rooms of the Survey Department, Cairo, with pyro-soda.

Standard squares were printed as follows:—On plate No. 1 itself, after exposure to standard candle at 6 feet for 1 minute. On a separate Rocket plate, developed in the same dish with No. 4, to candle at 6 feet for 1 minute and also for 10 minutes. On a separate Green-sensitive plate, developed in the same dish with No. 3, to a candle at 6 feet for 1 minute direct, and for 3 minutes through the same green screen as was used with Plate 3 (the latter exposure near the label: light meeting squares, screen, plate, in that order).

22. Reflection Apparatus in Horizontal Plane.

Slide.	Aperture.	Exposure.	Plate.	Remarks.
	in.	sec.		
1	$3\frac{3}{4}$	1	Rocket	
2	$3\frac{3}{4}$	5	,,	
3	$3\frac{3}{4}$	25	,,	
4	$1\frac{7}{8}$	5	,,	
5	$1\frac{7}{8}$	25	,,	Shaken.
6	$1\frac{7}{8}$	1	,,	

Captain Lyons put in the slides; Mr. Bennett exposed at the objective and changed the stop between Nos. 3 and 4. He gave me the note about No. 5 immediately after totality. All the plates were developed with pyro-soda by Mr. Kearney at the Survey Department, except No. 2, which was developed by him at Aswan. Standard squares were printed on No. 2, 20 seconds to candle at 6 feet.

23. Reflection Apparatus in Vertical Plane.

Slide.	Aperture.	Exposure.	Plate.
	in.	sec.	
1	2	5	Rocket.
2	2	25	,,

Mr. Herbert took entire charge of this instrument. Mr. Kearney developed No. 1 at Aswan and No. 2 in Cairo, both with pyro-soda.

Standard squares were impressed on a separate plate and developed in the same dish with No. 1: 60 seconds to candle at 6 feet.

Exposures to Sky Generally.

24. Two small open tubes of 1-inch aperture and 3-inch length were exposed for 10 seconds, one to the zenith and one to the corona generally, for

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comparison with similar exposures made on moonlight nights to the zenith and moon. The exposures during totality were made by Dr. W. M. Aders. Standard squares were always exposed to a candle at 6 feet and developed in the same dish with such plates.

The Goerz Lens.

25. At Mr. Maunder's request we took charge of a beautiful lens by Goerz for rapid exposures without clock driving. The lens was focussed on stars and then handed over to Mr. R. T. Günther, who took complete charge of it. His report is as follows:—

"August 30, 1905.

"Eclipse Station in Sheik's Tomb on top of hill overlooking Elephantine "Island.

Six plates exposed to Image by Goerz lens.

No. 3.	Slow.	4 secs. after commencement of totality.
„ 4.	Medium.	
„ 5.	Rapid.	
„ 6.	Rapid.	
„ 7.	Slow.	
„ 8.	Medium.	25 sec. before cessation of totality.

Note.—No. 5 may not be exposed at all, and No. 6 may be badly fogged.

"Average exposure of each plate was half a second.

"*Impressions.*—Owing to the extreme brightness of the corona, which rather dazzled* me, the intensity of illumination of the landscape appeared not to alter as much as I had been led to expect by reading of books. It is for this reason that I was not able to detect any well-marked shadow travel across the landscape, although I distinctly believed that at one instant the western landscape was dimmer than the eastern. There appeared to be no *sharp* delimitation between the two illuminated areas. No ripple waves of light were seen on a sandy slope to W.N.W. of observer, but as he had other things to think about, this slope did not have his undivided attention.

"R. T. Günther."

On developing the plates, Mr. Günther's fears with regard to 5 and 6 were found to be too well-founded. By stopping the development of the fogged plate it was possible to save a faint image of the prominences and inner corona.

* Mr. Günther covered up his eyes for some minutes before totality.

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The Reflector of 120*-feet focus.*

26. No satisfactory photographs of the corona were obtained with this instrument owing to several contributing causes. One of these causes alone, however, was sufficient in itself to completely spoil the results—viz., on developing the plates they were found to be strongly marked by the shape and grain of the woodwork of the plate-holder. The reason of this action of the woodwork is still under investigation, but it has already been found that it does not depend on any exposure to light. On discovering the curious action, the experiment was tried of putting a plate into the holder and locking it up in the current of the dark-room at the Survey Department for a day, so that it never saw any light at all. On development, strong markings of the woodwork of precisely the same character were found. Attempts will be made to get at the bottom of this matter, which is liable to seriously affect photographic work: to see, for instance, whether a high temperature is an important factor; but this investigation must be given separately. So far as it is possible to make out what there is on the plates in addition to these markings, it seems that the difficulties of mounting the telescope were not completely conquered. That very little appears beyond the prominences may be partly accounted for by the presence of the woodwork image and the necessity of stopping the development in consequence; but the definition is not good, and in one exposure the instrument was shaken.

It is, of course, a great disappointment to get practically no return for a good deal of work; and it only remains to record the facts leading up to it.

27. It should be remembered throughout that the eclipse work was not the main object of Mr. Reynolds' visit to Egypt. His main purpose, as already mentioned in § 1 (*c*), was to superintend the erection at the Helwan Observatory of a reflecting telescope, the 30-inch mirror of which was made by the late Dr. Common, and the mounting designed and constructed by Mr. Reynolds himself and presented to the Helwan Observatory. The eclipse of August 30 had an obvious influence on the time of his visit to Egypt, but by fixing a definite date for the delivery of the instrument, it seriously added to the amount of work to be done in the last six months in the scanty leisure of a busy man. This being premised, the following brief account of the enterprise will be better understood.

28. The project of taking out the long focus reflector was first seriously considered in the autumn of 1904. The instrument was mounted in the garden of the house at Birmingham where Mr. Reynolds resides (his father's house). The concave was placed horizontally due south of the cœlostat mirror, and in this position neither sun nor moon could of course be seen,

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using the cœlostat in the ordinary way. But Mr. Reynolds chiefly used the telescope for gazing purposes, and he had mounted the cœlostat mirror on pivots so that it could be tilted at any angle to the polar axis. Hence the sun or moon could be thrown on the concave, and focussed near the cœlostat at any time, though the image was no longer stationary. Using the instrument in this way, Mr. Reynolds had found out a good deal about its behaviour; he knew that good definition was only obtainable occasionally, but that at times it was obtainable; also that the instrument was liable to changes of focus.

29. On his kind invitation I paid two visits to Birmingham to see the instrument. On the first occasion, unfortunately, a dense fog came on and nothing could be done. On the second the moon was full and bright, but it was a frosty night. The focus was found to be fully 1 foot within its previous record, and the definition was not good. On discussing the matter it was decided that the prospects of success were perhaps too slender to justify undertaking the enterprise as it stood, but Mr. Reynolds determined to make a concave of shorter focus (about 80 feet) to see whether good definition could not be secured more regularly, and he further visited the works of Messrs. Chance and Co. to see whether some glass could not be obtained which would be less subject to temperature effects. Messrs. Chance and Co. were able to recommend such a glass, and a disc was ordered. But now the work on the 30-inch needed attention, and it was found impossible to provide this new disc in time. Accordingly it was decided to give up the idea of a long focus telescope and to use the Helwan 30-inch mirror in conjunction with the cœlostat, enlarging the primary image with a 6-inch enlarging camera.

30. On July 17, however, Mr. Reynolds, in writing about this plan, mentioned incidentally that he had had a very fine view of a sun-spot the day before with the 120-foot; that the "definition at instants was certainly very good." In consequence I suggested that perhaps after all it might be well to revert to the original experiment. It was the one for which a sub-committee had been specially appointed, and an opportunity of trying it was not likely to recur for some time. Moreover, although success was problematical, there seemed a fair chance of it, and if it could be obtained the gain might be great. Mr. Reynolds concurred and it was determined to take the risk. Time was, of course, running short, but it was arranged that I should select a site in advance and build the piers, and that Mr. Reynolds should get ready the instrument to bring out with him later.

31. On arriving at Aswan, a site for the instrument was originally

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selected in the hotel grounds on Elephantine Island, but as already mentioned in § 4, a new site was chosen at the railway station when it was found how little time was available. Here a pier 8 feet × 5 feet was erected on the railway platform for the cœlostat and camera; and 120 feet away, on the enclosure boundary, a wall several feet in length was built for the concave, to give a range both in focal length and in azimuth of the reflected ray. The azimuth for horizontal reflection was 10° south of west, but this took the rays rather close to a palm tree, and it was felt that it might be desirable to choose an azimuth further north with a corresponding depression of the ray.

The instrument arrived at Aswan late on August 26. Early next morning the work of mounting the cœlostat was commenced; and it was practically completed and the necessary adjustments made by the afternoon. The sun's rays were then flashed across towards the other pier to select the exact place for the concave, and immediately a serious difficulty presented itself. It has been already mentioned that the plane mirror was provided with an additional movement, being mounted on an axis perpendicular to the polar axis. One of the bosses at the end of this axis came into contact with the backbone of the cœlostat and prevented the mirror from assuming a position near the vertical. The sun's altitude at eclipse was 24°, and to reflect its rays horizontally the mirror must be inclined only 12° to the vertical, whereas the minimum possible inclination was greater. How much greater it was not easy to say, for it was already past the time of the eclipse; and only a rough estimate could be formed, from observation of the place where the rays crossed a certain palm tree, at a given time, of the direction they would take at eclipse time. At night attempts were made to use Altair, the declination of which was within 30′ of that of the sun at eclipse, to estimate the position more closely; but there is some difficulty in identifying stars from 120 feet away in a mirror which subtends an angle of only about a degree, and it was felt that the procedure could not be trusted. Next morning it was found by observing the time taken by the sun's rays to rise from the horizontal position to that marked on the palm tree that the amount of alteration required was not very large, and it was hoped that by chipping away the cast-iron backbone of the cœlostat, enough might be done.

A segment of about ½ inch in depth was chipped away during the day, shelters erected for the two mirrors, and some necessary repairs made on the clock, which had been broken in transit; and at eclipse time the reflected rays were anxiously observed. It was seen that enough had not been done; the mirror came to a stop just before totality time. It was

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then decided to tilt over the whole stand, by wedging up from the east. This involved readjustment of the instrument and a certain loss of stability; but there seemed to be no choice. To restore stability as far as possible sand and earth were packed all round the base. This was not completed till the morning of Tuesday, August 29. Meanwhile it had become clear that the pier for the concave must be raised, and all idea of a depressed ray, with better clearance of the palm tree, given up. Instead of building up bricks, which would have taken valuable time, a pile of steel railway sleepers, kindly lent by the authorities, was made, and the concave mounted upon them.

Having settled the direction of the ray, a tube for it was made by mounting 10 stout square wooden frames on posts, running wire through staples in the frames, and stretching canvas along the wire. This work took almost every available minute up to the time of eclipse, but all was actually ready in time. The ground under the tube had, as already mentioned, been thoroughly soaked by the local fire-brigade, and radiation effects thereby considerably reduced. Against air-tremor nothing could, of course, be done; but a new and formidable source of alarm presented itself almost at the last. A powerful steamer went down the river and the whole instrument shook to the paddle wheels. Apparently the ground transmits vibrations with terrible facility. When this was realised, all idea of a long exposure was abandoned, and it was determined to confine the exposures to two or three seconds. Even then, as the event proved, shake was not avoided in one exposure.

During totality Mr. Reynolds adjusted the cœlostat so as to throw the selected portion of the sun's limb on to the plate, Mr. Keeling put in the plates and the focussing screen for adjusting them, and Mr. E. M. Dowson watched the clock, which showed irregularities in driving sometimes. It has been already mentioned that the plates, when developed, were spoiled by some action of the wooden plate-holders, which gave a strong image of the woodwork.

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